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Introduction

THE International Union of Forest Research Organizations (IUFRO) has sponsored several international provenance tests. This is a report on the practical aspects of an IUFRO provenance test with Scotch pine in New York.

In May 1938, the New York State Conservation Department received 53 lots of Scotch pine seed for provenance testing from Dr. H. I. Baldwin, research forester, New Hampshire Forest and Recreation Division. Of these seedlots, 44 were part of the 1938 provenance test initiated by Dr. Werner Schmidt, at that time chairman of the IUFRO Subcommittee for Forest Seed and Forest Tree Races. Dr. Baldwin had received the IUFRO seed from Dr. Olof Langlet for distribution in the United States. The other nineteen seedlots (F-numbers) were non-IUFRO provenances that Dr. Baldwin had received directly from European forest experiment stations.

Results of a New Hampshire test of most of the provenances included in this study have been published by Baldwin *(1, 2, 3)* and Wright and Baldwin *(7)*. The literature on older provenance tests with Scotch pine has been reviewed by Wright and Baldwin *(7)* and Langlet *(5)*.

The seed received by the New York State Conservation Department was sown in the Saratoga State Forest Nursery in the spring of 1938. The stock was outplanted in 1940, 1941, and 1942 in several localities on state forests as 2-0 seedlings and as 2-1 and 2-2 transplants respectively.

The Conservation Department requested the cooperation of the Northeastern Forest Experiment Station in evaluating the Scotch pine test in 1956; and two test plantations, 18 years old from seed, on the Herkimer No. 1 State Reforestation Area near Hinckley, N. Y., were selected for remeasurement. One plantation had been established in 1940 with 35 seedlots, the other in 1942 wich 8 slow-growing seedlots of northern origin that did not reach suitable size for outplanting until they were 4 years old in the nursery. This report will be limited to the practical aspects of this 18-year-old provenance test; the genetical aspects will be presented by the senior author in a separate publication.

Materials and Methods

SEEDLOTS

The geographic locations of the provenances for which latitude and longitude are available are shown in figure 1. Data on the progenies outplanted in 1940 are recorded in table 1; the provenance, latitude, longitude, and elevation above sea level of the IUFRO seedlots are taken from Langlet *(5)*. Data on latitude, longitude, and elevation of seedlots F-232 and F-246 are not available (personal communication from Dr. Baldwin). The northern Scandinavian provenances outplanted in 1942 are listed in table 2; and latitude, longitude, and elevation data for these are also from Langlet *(5)*.

The seedlot listed as "B" (table 1) was 1936 seed from natural regeneration of Scotch pine originally planted between 1870 and 1890 at Woodgate and Boonville, N. Y. York and Littlefield, in their study of the Boonville Scotch pine *(8)*, concluded that the geographic origin of the parent stock was most probably southern Germany—but more specific information is not available. The trees in the Boonville area exhibit rather good stem form. Seed of this origin has been used extensively for reforestation in New York State, particularly during the past 20 years, because the trees retain their green foliage color during the fall and winter, thus increasing their value as Christmas trees.

The seedlot designated as "H.B." was distributed by Herbst Brothers, New York, as "H.B. Special Seed". The data on provenance, latitude, longitude, and elevation are taken from their sales brochure dated March 1936. The parent trees were described as particularly rapid-growing and straight-boled. Since the brochure stated that the parent stands stemmed from seed obtained in 1772 from selected parent trees throughout Europe that were especially rapid-growing and straight-boled, the original provenance of this seedlot is uncertain.

PLANTATION SITE

The 1940 and 1942 plantations in Herkimer County, New York, are located at 43° 18′ north latitude and 75° 07′ west longitude. The plantation site lies 0.8 airline mile south of the village of Hinckley. The area, on the southern fringe of the Adirondack Mountain region, is generally flat, with an elevation of 1,360 feet. The soil type is Merrimac fine sand. The following climatological data for the area are taken from Mordoff *(6)*.

Average date of last killing frost in spring—approximately May 31.

Average date of the first killing frost in fall—between September 20 to 30.

Average length of the growing season—120 to 135 days.

Mean temperature for the growing season—60° to 65°F.

Mean annual precipitation—40 to 50 inches.

Mean precipitation for the growing season—21+ inches.

Mean annual snowfall—80 to 100 inches.

Mean annual relative humidity—
80 percent.

The planting site was an abandoned cultivated field with a light sod. Before planting, the site received no preparation other than the removal by cutting of a few wild cherry and wild apple trees, and some spirea. At the time of the 1940 planting it was noted that the area was heavily infested with June beetles *(Phyllophaga).*

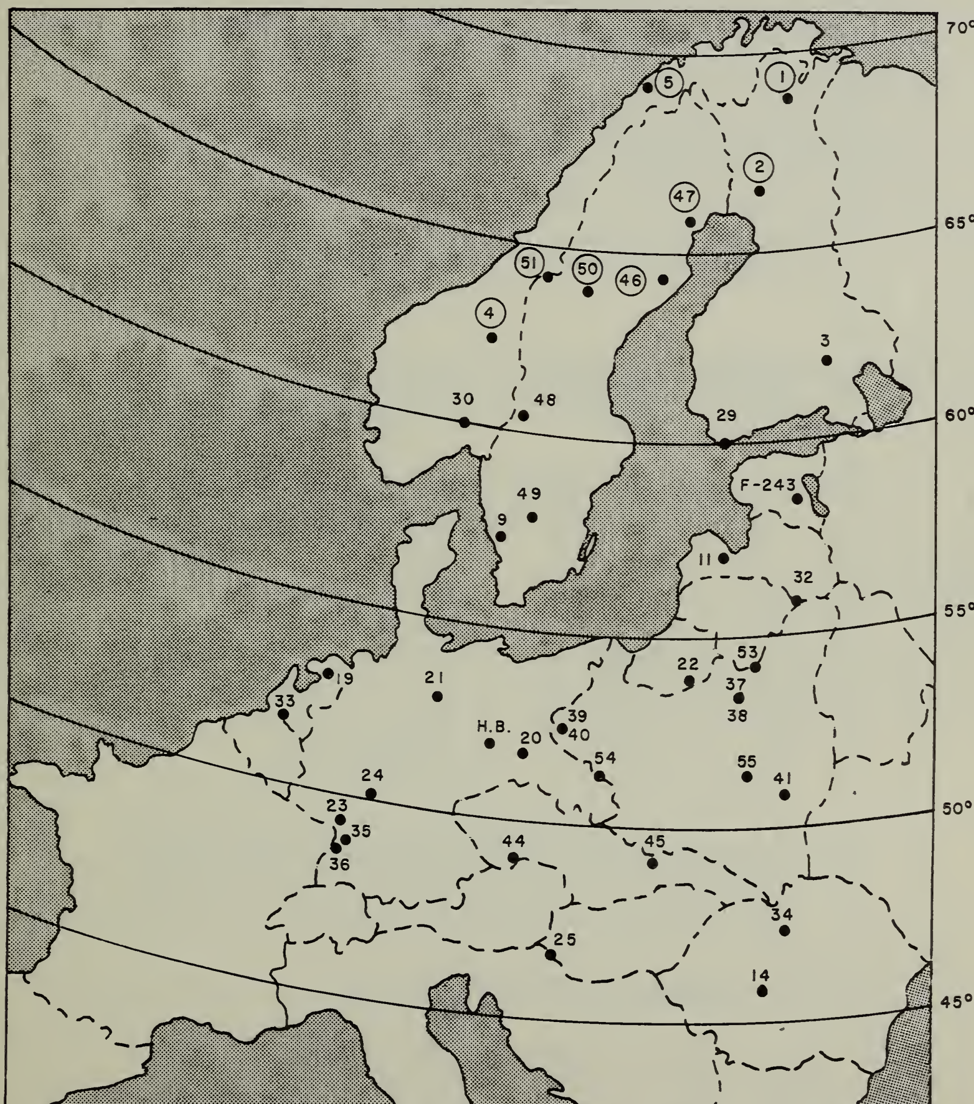

Figure 1.—Location of the parent stands of the progenies included in this provenance test. The circled numbers indicate the slow-growing provenances outplanted in 1942.

Table 1.—Data on seedlots in the Scotch pine provenance test outplanted in 1940 on Herkimer State Forest, Hinckley, N. Y.

Seedlot number	Provenance	North latitude	East longitude	Elevation	Needle length**	Average survival***	Average height***	Average d.b.h.***
				Meters	cm.	Percent	Feet	Inches
3	Säaminki (Niittylahti), Finland	61°44'	28°55'	85	5.08	75	17.47	3.57
9	Tönnersjöheden, Sweden	56°40'	13°08'	100	--	83	20.47	4.60
11	Vecmokas, Latvia	57°03'	23°10'	80	9.12	86	22.57	4.83
14	Talmacel, Rumania	45°40'	24°08'	600	8.69	82	22.33	4.33
19*	Diever (Smilde), Netherlands	52°51'	6°21'	10	10.34	74	24.87	5.37
20	Pförten, Poland	51°47'	14°46'	85	10.44	76	26.90	5.63
21	Göddenstedt (Jg. 80), Germany	52°59'	10°50'	75	9.30	73	26.27	5.10
22	Cruttinen (Jg. 240a), Poland	53°41'	21°26'	120	8.68	85	26.43	5.37
23	Elmstein (Erfenstein), Germany	49°20'	7°57'	325	--	73	26.10	5.13
24	Zellhausen (Jg. 27), Germany	50°01'	9°00'	140	--	76	26.83	5.63
25	Lenti, Hungary	46°38'	16°33'	250	--	84	26.13	5.77
29	Bromarv (Solböle), Finland	60°03'	23°06'	15	7.71	78	19.97	4.17
30	Modum, Norway	60°04'	10°00'	300	7.61	92	17.97	3.77
32	Griva, Latvia	55°58'	26°15'	160	8.63	79	25.00	5.27
33*	Breda (Mastbosch), Netherlands	51°34'	4°46'	10	10.93	76	26.63	5.87
34	Tinoava, Rumania	47°24'	25°22'	910	8.35	71	20.63	3.60
35	Langensteinbach, Germany	48°55'	8°30'	260	12.34	71	27.27	6.07
36	Langenbrand, Germany	48°47'	8°40'	525	11.28	80	26.50	4.87
37	Suprasl (A), Poland	53°13'	23°22'	160	10.60	89	26.27	5.47
38	Suprasl (B), Poland	53°13'	23°22'	160	10.07	75	26.27	5.33
39	Bolewice (A), Poland	52°24'	16°10'	90	10.20	70	26.33	5.20
40	Bolewice (B), Poland	52°24'	16°10'	90	11.31	83	26.17	5.23
41	Susk (A), Poland	50°50'	26°00'	185	--	74	26.43	5.67
44	Trebon, Czechoslovakia	49°00'	14°45'	450	--	84	26.63	5.50
45	High Tatra - Vysoke Tatry, Czechoslovakia	49°09'	20°13'	650	--	76	23.17	4.83
48	Vitsand, Sweden	60°23'	12°55'	175	6.48	73	17.57	3.73
49	Axamo, Sweden	57°46'	14°03'	225	7.91	77	19.13	4.17
53	Mustejki, Poland	54°08'	24°25'	130	--	83	26.53	5.83
54	Rychtal, Poland	51°12'	17°55'	190	--	69	26.20	5.47
55	Luboml, Poland	51°15'	24°05'	195	--	74	25.33	5.67
F-232	Hungary	--	--	--	8.12	65	25.53	5.63
F-243	Tartu, Esthonia	58°--	27°--	--	--	83	24.73	4.27
F-246*	Belgium	--	--	--	--	83	26.90	5.83
B	Probably Germany	--	--	--	--	78	24.47	5.67
H.B.*	Neuhaldensleben, Germany	52°--	12°--	90	--	85	25.77	6.17

*Planted stands. **2-year-old needles on 3-year-old seedlings. ***18-year-old trees.

PLANTATION ESTABLISHMENT AND CULTURE

The 1940 planting stock was lifted at the Saratoga nursery on April 29, shipped by truck to the planting site, heeled-in from May 6 to 13, and planted on May 13 and 14. The 1942 planting stock was lifted on April 13, shipped to the planting site by truck on April 14, and planted on the same day. Both the 1940 and 1942 plantings were made in mattock-slits at a spacing of 8 x 8 feet. After planting, there was no replacement of dead trees; and no weeding, thinning, or any other type of cultural work was done in these plantations.

EXPERIMENTAL DESIGN

The nursery phase of this study was under the supervision of E. J. Eliason. Seedlots were grown without randomization in two sections of the Saratoga Nursery designated as "the old nursery" and "the new nursery".

The two test plantations in Herkimer County were established under the supervision of E. W. Littlefield. In both plantations the seedlots were planted in single-row plots of approximately 50 seedlings per row in each of three replications, with 20 feet between replicates; the row-plots were not randomized within replicates. In the 1940 planting the seedlots were planted in numerical order from east to west with Boonville (B) as the east border row, the Herbst Brothers Special (H.B.) as the west border row in each replicate. The seedlots used in the 1942 plantation were planted in numerical order with seedlot 1 on the west side and seedlot 51 on the east side of each replicate.

OBSERVATIONS AND MEASUREMENTS

First and Second Years

Fall needle color of the seedlings was evaluated on 36 of the 43 seedlots by E. J. Eliason on October 4, 1938, and on November 15, 1939. The average heights of the seedlots at the end of the first and second years were ob-

Table 2.—Data on seedlots in the Scotch pine provenance test outplanted in 1942 on Herkimer State Forest, Hinckley, N. Y.

Seedlot number	Provenance	North latitude	East longitude	Elevation	Needle length*	Average height**
				Meters	Cm.	Feet
1	Inari (Kyro)	68°40'	27°37'	140	5.08	5.40
2	Rovaniemi (Kivalo)	66°25'	26°36'	250	5.06	7.33
4	Tonset	62°22'	10°48'	550	5.11	11.77
5	Malselv (Bjorkli)	69°06'	18°50'	75	4.49	7.80
46	Vindeln (Kulbacksliden)	64°11'	19°35'	270	4.71	12.33
47	Brannberg	65°48'	21°16'	100	4.87	10.57
50	Stromsund	63°50'	15°33'	300	6.25	11.63
51	Svenskadalen	64°02'	13°04'	500	5.51	11.87

*2-year-old needles on 3-year-old seedlings. **18-year-old trees.

tained from measurements of 10 randomly selected trees of each provenance.

Instructions for evaluating needle length, received through Dr. Baldwin, called for measurements on 100 plants, the needles to be taken from the center of the internode. Length of the 1939 and 1940 needles were measured by Messrs. Kopp and LaTour in May 1941. For the 1939 needles, one needle fascicle was measured on either 50 or 100 randomly selected seedlings per seedlot, with the exception of seedlots 1 (20 seedlings) and 2 (25 seedlings). The measurements of the 1940 needles were made on 50 seedlings per provenance.

Eighteenth Year

1940 Plantation.—Measurements and observations were made between August 24 and 31, 1956, by personnel of the Northeastern Forest Experiment Station (E. J. Schreiner, W. J. Gabriel, and H. C. Kettlewood) on total height, d.b.h., branch angle, survival, basal crook or sweep, trunk crook, trunk lean or sweep, forking, windthrow, and porcupine damage. Measurements for comparison of average branch diameter were considered and attempted, but preliminary trials indicated that time would not have been available for measurements of sufficient accuracy to provide reliable estimates for seedlot comparisons.

D.b.h., height, and branch angle were measured on 48 trees per seedlot, i.e., 16 trees per seedlot per replicate. The measured trees were numbers 2 to 5, 15 to 18, 33 to 36, and the 4 trees immediately preceding the last tree in each row-plot; where the trees listed were dead or missing the nearest trees in the row were substituted. Total height was measured to the nearest 0.5 foot with a telescopic measuring pole. The top of the pole was lined up with the top of the tree by an observer on a ladder at tree-top level; the height was read by the man controlling the pole.

D.b.h. was measured with calipers to the nearest 0.1 inch—the average of the largest and smallest diameters. Branch angle was measured at the base of the branch with a goniometer; the value recorded for individual trees, in 5-degree classes, was the average of several branches originating between 4 and 10 feet above the ground.

All living trees (except windthrows) were rated for basal crook or sweep,

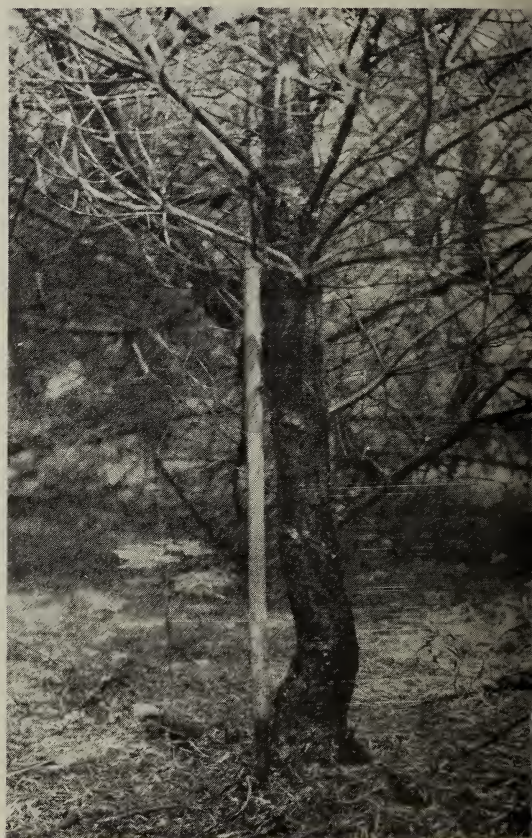

Figure 2.—Basal crook with more than 2 inches offset.

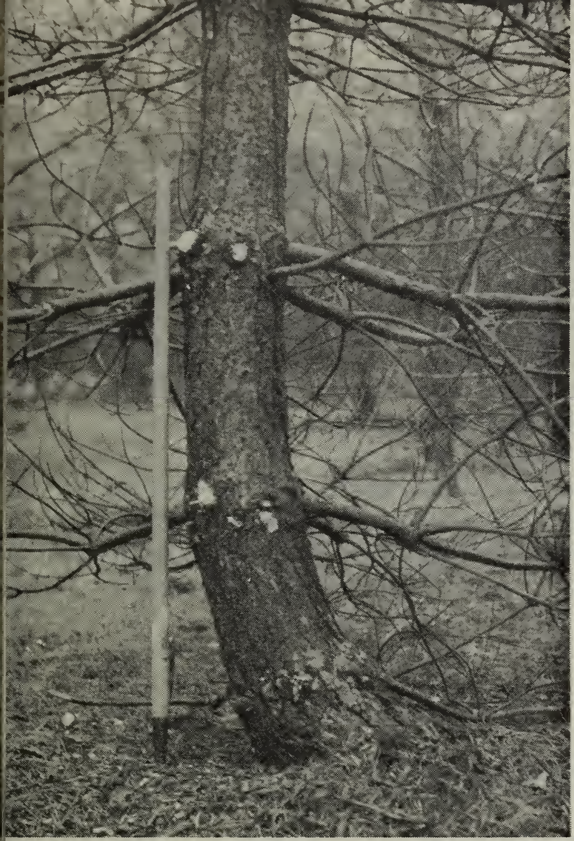

Figure 3.—Basal sweep with more than 2 inches offset.

Figure 4.—Trunk crook with less than 2 inches offset.

Figure 5.—Trunk crook with more than 2 inches offset.

Figure 6.—Trunk sweep with more than 2 inches offset.

trunk crook, sweep or lean, forking, and porcupine damage. Basal crook or sweep applies to such malformation in the basal 2 feet of the trunk. Basal and upper-trunk crook, sweep, or lean were recorded in two categories depending on the amount of offset in the vertical axis of the tree: (1) less than 2 inches, and (2) 2 inches or more (figs. 2 to 6).

It was essential to view each tree from at least two adjacent sides to evaluate crook, sweep, and lean accurately. Trees with two or more leaders that persisted long enough to produce an offset of the main stem of 2 inches or more were included as forked trees. Windthrow included trees that were broken off or had been sufficiently uprooted to prevent eventual recovery regardless of whether they were dead or alive at the time these measurements were made.

1942 Plantation.—Only total height was measured because of lack of time and the slow growth rate of the northern seedlots in this plantation.

Analysis and Discussion of Results

FALL NEEDLE COLOR OF SEEDLING TREES

Fall needle color of Scotch pine is important to Christmas tree growers because the public generally prefers green trees. The fall color of the 1-year seedlings (on October 4) was rated in 5 color classes from purple to green, that of the 2-year seedlings (on November 15) in 5 classes from yellow to green (table 3). Although in many cases there was a difference of one rating grade, fall coloration was reasonably uniform between the old and new nursery sites. Twelve of these provenances would be satisfactory if seedling ratings of 4 and 5 are accepted as indicative of needle color in 6- to 10-year-old trees.

The following summary of the data in table 3 for seedlots for which latitude is available confirms the results of numerous investigations that green winter foliage is characteristic of Scotch pine of southern origin:

Rating class	*North latitude*		
	Maximum	*Average*	*Minimum*
4-5	52°59′	49°13′	45°40′
4	53°41′	51°59′	50°50′
3-4	60°04′	57°58′	55°58′
1-3	69°06′	63°47′	60°23′

RELATIONSHIP OF NURSERY AND 18-YEAR HEIGHT

The possibility of predicting relative height at the end of the rotation, or at intermediate periods, on the basis of relative seedling height is of great importance to foresters interested in provenance tests, selection of parent trees for seed orchards, and selection of progenies produced by controlled breeding. The correlations of 18-year heights in the 1940 plantations with first-year and second-year heights in the "new nursery" were significant at the 5-percent level; the correlations of

Table 3.—Fall needle color of the 1- and 2-year-old seedlings, Saratoga State Nursery, N. Y., rated by color classes.*

Seedlot number	North latitude	1-year-old seedlings		2-year-old seedlings		Range
		Old nursery	New nursery	Old nursery	New nursery	
25	46°38'	5	--	5	--	5
(14)**	45°40'	4	4	5	5	4-5
21	52°59'	5	4	4	4	4-5
23	49°20'	5	4	5	4	4-5
24	50°01'	4	4	5	4	4-5
33	51°34'	4	4	5	4	4-5
35	48°55'	4	4	5	4	4-5
(36)	48°47'	5	4	4	4	4-5
44	49°00'	4	--	5	--	4-5
(45)	49°09'	5	--	4	--	4-5
F-232	--	4	5	4	5	4-5
B	--	--	4	--	5	4-5
19	52°51'	4	4	4	4	4
20	51°47'	4	4	4	4	4
22	53°41'	5	4	4	4	4
(34)	47°24'	4	4	4	4	4
37	53°13'	4	4	4	4	4
38	53°13'	4	4	4	4	4
39	52°24'	4	4	4	4	4
40	52°24'	4	4	4	4	4
41	50°50'	4	4	4	4	4
F-246	--	4	--	4	--	4
H.B.	52°00'	4	4	4	4	4
11	57°03'	3	4	3	3	3-4
32	55°58'	4	4	4	3	3-4
9	56°40'	3	--	3	--	3
29	60°03'	3	3	3	3	3
30	60°04'	3	3	3	3	3
F-243	58°00'	3	--	3	--	3
3	61°44'	3	3	2	--	2-3
48	60°23'	3	3	2	3	2-3
49	57°46'	3	3	2	3	2-3
4	62°22'	2	2	2	2	2
5	69°06'	2	--	2	2	2
1	68°40'	1	1	2	1	1-2
2	66°25'	2	2	2	1	1-2

* 1-year-old seedlings:
1 = Purple
2 = Intermediate
3 = Purple green
4 = Intermediate
5 = Green

2-year-old seedlings:
1 = Yellow
2 = Intermediate
3 = Yellow-green
4 = Intermediate
5 = Green

** Numbers in parentheses are the high-altitude seedlots.

18-year heights with first-year and second-year heights in the "old nursery", and with average first-year and second-year heights in both nurseries, were significant at the 1-percent level. (The relationship between 18-year heights and average first- and second-year heights in both nurseries is shown in figures 7 and 8, respectively.) The lower significance of the correlation between 18-year heights and heights in the "new nursery" may have been due to greater soil heterogeneity on the new land than on the old nursery site.

Too often a statistically significant correlation between nursery height and height at later ages is presumed

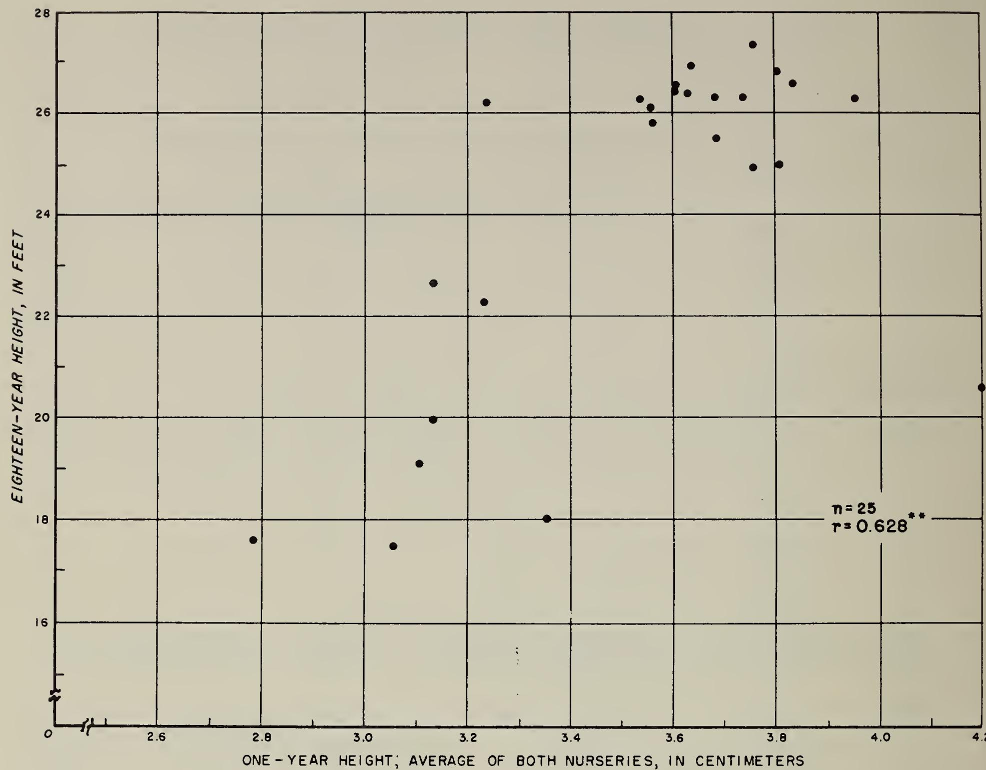

Figure 7. — Relationship between 18-year plantation height and average 1-year height in both nurseries. **Correlation coefficient at the 1-percent level of significance = 0.505.

to indicate that selection on the basis of such juvenile growth is practicable; that it is safe to select for mature growth on the basis of relative height growth in the nursery. Although these correlations between nursery and 18-year height are statistically significant, the correlations account for a relatively small percent of the variation in the 18-year average heights. In this study the variation associated with the correlated changes in 18-year height and nursery height, on an approximate percent basis, are as follows:

	1-year height (Percent)	*2-year height (Percent)*
Old nursery	30	34
New nursery	21	23
Average, both nurseries	39	37

But even this information on the variability accounted for by the correlations does not give a practical estimate of the results that would have been obtained by selecting on the basis of 1- and 2-year height growth. This is more clearly indicated by assuming selections on the basis of nursery height and tabulating these against the 18-year height. For this purpose the seedlots were ranked in five arbitrary classes, each class covering 20 percent of the respective range in height in the 18-year-old plantation and in the two nurseries at 1 and 2 years.

In table 4 the 18 seedlots ranked 1 on the basis of average height at 18 years (the top 20 percent of the total range in average height) are listed in columns 1 and 2; columns 3 to 8 show the ranking of these seedlots on the basis of first- and second-year heights in the old and new nurseries and their average heights in both nurseries. The number and percent of seedlots rated in the top 20 percent at 18 years that would have been selected on the basis of the top 20 percent in the nursery are recorded at the bottom of the respective columns.

Selection on the basis of first- and second-year heights in each nursery would have included only 5.6 to 16.7 percent of the seedlots in the top 20 percent at 18 years; selection based on the average of both nurseries in the first year would have included only 6.7 percent of these seedlots and in the second year only 40 percent. However, it should be noted that with averages based on more than 10 seed-

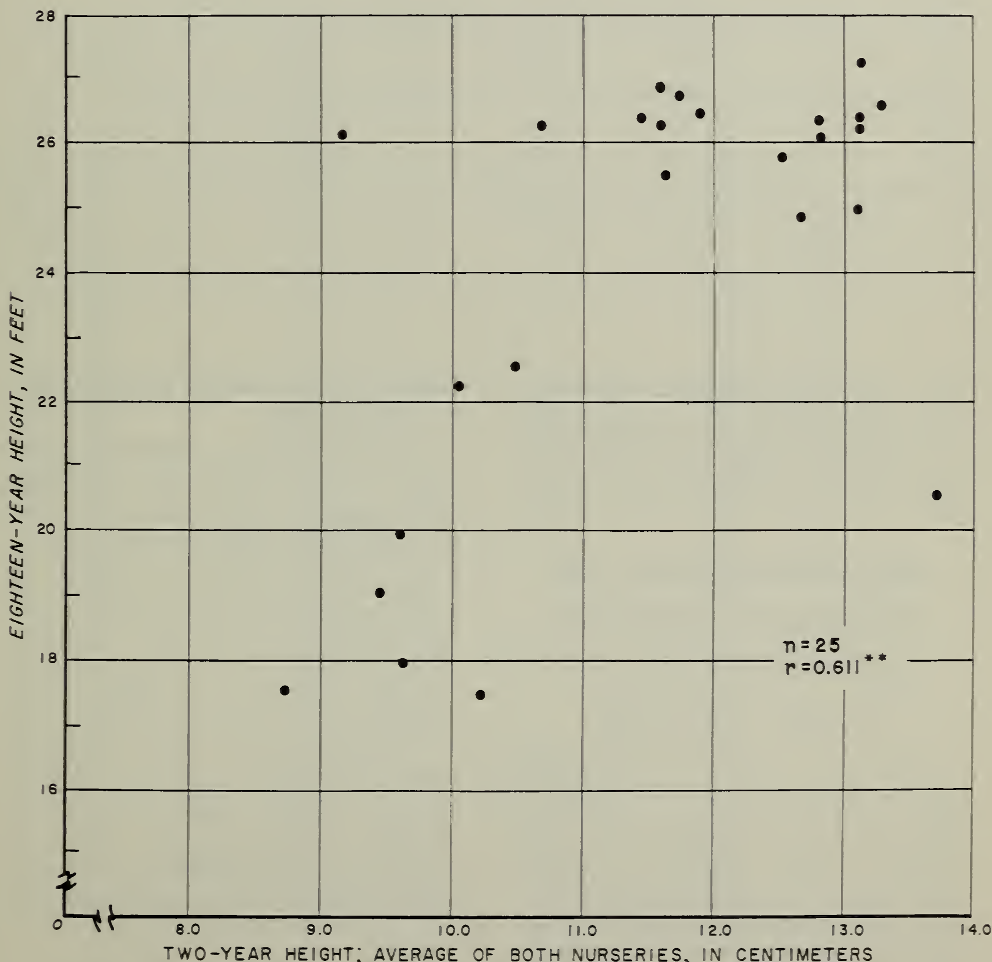

Figure 8.—Relationship between 18-year plantation height and average 2-year height in both nurseries. **Correlation coefficient at the 1-percent level of significance = 0.505.

Table 4.—Nursery height rank of seedlots in the top 20-percent height rank at 18 years

Seedlot number	18-year	Old nursery		New nursery		Both nurseries	
		1st year	2nd year	1st year	2nd year	1st year	2nd year
35	1	2	1	3	3	2	1
246	1	1	1	--	--	--	--
20	1	2	3	3	3	2	3
24	1	2	4	2	2	2	2
44	1	4	4	--	--	--	--
33	1	2	1	1	4	2	1
36	1	2	2	4	4	3	2
22	1	3	2	2	2	3	1
41	1	3	5	2	1	2	3
21	1	2	2	4	2	3	1
37	1	2	2	1	2	1	1
38	1	2	3	3	3	2	3
39	1	2	5	3	2	2	4
40	1	3	5	5	5	4	5
23	1	3	3	2	1	3	1
25	1	4	2	--	--	--	--
H.B.	1	3	2	3	3	3	2
232	1	2	2	3	5	2	3
Rank 1	No.	1	3	2	2	1	6
	Percent	5.6	16.7	13.3	13.3	6.7	40.0

lings, and with additional replication and randomization, the average height in the nursery might have been more highly correlated with 18-year height.

RELATIONSHIP OF SEEDLING NEEDLE LENGTH AND 18-YEAR VOLUME

Since the 2-year-old seedlings had been transplanted in the spring of 1940, the average length of the 1940 needles of every seedlot was shorter than their 1939 needle length. However, the correlation between 1939 and 1940 needle lengths was highly significant (r=0.860). Only the 1939 needle lengths are included in this report (tables 1 and 2) because the 1940 lengths are confounded with the effect of transplanting.

The correlation between needle length of the 2-year-old seedlings. (1939 needles) and volume per acre at 18 years was highly significant (r = 0.809). This correlation accounts for approximately 65 percent of the variation associated with the correlated 18-year height and average needle length of the 2-year-old seedlings. This is much higher than the percentages listed previously for the correlation between 18-year height and nursery height. Seedling needle length in Scotch pine may therefore be a more useful criterion for juvenile selection.

1942 PLANTATION

The average heights of the seedlings in this plantation are listed in table 2. The analysis of variance indicated no significance between replicates, but highly significant differences between seedlots:

	D.f.	Variance	F[1]
Between replicates	2	0.065	0.031
Between seedlots	7	20.55	9.74**
Remainder	14	2.11	—

[1] F value for significance at the 1-percent level with 7 and 14 d.f.=4.28.

Table 5.—Comparisons of mean survival and mean volume per acre, studentized range test*

Survival: Seedlot number**	Survival	Volume per acre: Seedlot number**	Volume
	Percent		Cu.ft.
30	92	35	973
37	89	H.B.	947
11	86	33	892
H.B.	85	246	885
22	85	53	874
25	84	25	839
44	84	20	825
243	83	24	823
246	83	41	820
9	83	44	791
40	83	232	790
53	83	55	786
(14)	82	37	760
(36)	80	54	759
32	79	B	757
29	78	22	740
B	78	38	722
49	77	19	696
33	76	40	692
24	76	39	687
20	76	32	671
(45)	76	23	664
3	75	21	658
38	75	(36)	611
41	74	(45)	524
19	74	11	510
55	74	243	439
48	73	9	425
23	73	(14)	411
21	73	29	336
35	71	49	331
(34)	71	(34)	260
39	70	30	250
54	69	48	239
232	65	3	216

*Brackets inclose means that are not significantly different at the 5-percent level; comparisons for survival are based on transformed values.

**Numbers in parentheses are the high-altitude seedlots.

These northern Scandinavian provenances (average heights 5.40 feet to 12.33 feet in 18 years) are too slow-growing to be of practical value even for Christmas tree production in this region.

1940 PLANTATION

Survival

Percent survival is given in table 1. Windthrows that were not expected to recover were counted as dead trees. The analysis of variance (based on the angular transformation of the percent data) indicated that there were highly significant differences between replicates and between seedlots:

	D.f.	*Variance*	$F^{1/}$
Between replicates	2	145.33	6.51**
Between seedlots	34	60.83	2.73**
Remainder	68	22.32	—

[1/]F value for significance at the 1-percent level with 2 and 68 d.f. <4.95; with 34 and 68 d.f. <2.00.

It is most probable that the differences in survival between seedlots was strongly influenced by the combined effect of the severe but spotty beetle damage in the years immediately after plantation establishment and the lack of randomization within replicates.

The seedlot means for survival, compared by the sequential studentized range test described by Keuls *(4)*, fall into three very broad, overlapping groups (table 5). Therefore it is not possible to segregate the provenances into statistically valid groups.

Branch Angle and Porcupine Damage

The range in the average branch angle of the individual seedlots was from 50° to 56°, but the differences between seedlots were not statistically significant. Porcupine damage was too sparse and erratic to be considered.

Height and Diameter

At 8 x 8 feet spacing the plantation was just beginning to close at 18 years and there was no indication that at this wide spacing the more rapid-growing seedlots were affecting the height or diameter growth of slower growing provenances in adjacent rows. Wright and Baldwin, in their report on the Hillsboro test *(7,* p. 11), also found no significant difference between row-plots and large rectangular plots for any of the provenances at the close spacing of 4 x 4 feet, although crown closure had taken place several years previously. The location of seedlots B and H.B. as border rows apparently did not effect their height growth, but it is possible that the border effect may have slightly increased their diameter growth.

Height and d.b.h. are listed in table 1. The analyses of variance for height and d.b.h. indicated highly significant differences between seedlots but no significant difference between replicates:

	D.f.	*Variance*		$F^{1/}$	
		Height	*D.b.h.*	*Height*	*D.b.h.*
Between replicates	2	1.44	0.24	1.20	3.00
Between seedlots	34	27.12	1.62	22.60**	20.25**
Remainder	68	1.20	.08	—	—

[1/]F value for significance at the 1-percent level with 34 and 68 d.f. <2.00.

To examine the homogeneity of this site more closely, an analysis of variance for height growth was made, based on the four-tree group averages (trees 2-5, 15-18, etc.). This also indicated no significant difference in height between the group averages:

	D.f.	*Variance*	$F^{1/}$
Between 4-tree groups	11	3.75	1.08
Between seedlots	34	108.71	31.38**
Remainder	374	3.47	—

1/F value for significance at the 1-percent level with 34 and 374 d.f. <1.79.

This has been an unusually uniform site for the growth of Scotch pine and, as in the study reported by Wright and Baldwin for 4 x 4 feet spacings, there was no apparent competitive effect on the growth of adjacent seedlots. Therefore it was concluded that, although there was no randomization within replicates, the analysis of variance could be safely applied to the growth data obtained from these trees.

PRACTICAL EVALUATION OF THE PROVENANCES

The general procedure for reporting provenance tests has been to evaluate survival, height, diameter, stem form, branch characteristics, etc., and attempt to correlate these characteristics with the geographic location and environment of the place of origin; such a presentation is being prepared by the senior author for separate publication. In this report we have attempted to evaluate the provenances for more immediate practical use by the forest manager who is interested in the possibilities of Scotch pine in this region. Instead of evaluating height, diameter, and stem form independently, we have estimated, for each seedlot, the average total volume per acre, and the average volume and number of trees per acre on the basis of trunk classes that we believe are fairly indicative of the eventual timber quality. Estimates are for volume and number of trees at 18 years; there are no data available to justify projection of the 18-year data to end-of-rotation estimates.

Volume

Volume of the average tree for each provenance was computed as a cone from the average 18-year total height and d.b.h. outside the bark. Although survival was highly significant, it is impractical to apply individual or group averages because the provenance means fall into three very broadly overlapping groups. For this reason the average survival for all provenances, 78 percent, was used for estimating the number of living trees per acre at 18 years. With 8 x 8 feet spacing this is 531 trees per acre (0.78 × 681); average total volumes were computed on the basis of this number. For each trunk class the number of trees per acre at 18 years was estimated by multiplying 531 by the percent of living trees in the respective trunk class, and the average volume per acre was then calculated by multiplying the estimated number of trees by the volume of the average tree.

Total Volume Per Acre

The analysis of variance indicated that differences between seedlots in cubic feet per acre were highly significant:

	D.f.	*Variance*	*F*[1]
Between replicates	2	7,468.45	0.91
Between seedlots	34	145,863.75	17.71**
Remainder	68	8,235.77	—

[1]F value for significance at the 1-percent level with 34 and 68 d.f. <2.00.

In table 5 the seedlots are arranged in descending order to show estimated average volume per acre for sequential tests of all comparisons among the means. The following tabulation is based on the provenances in the eight overlapping groups for which latitude is available, exclusive of the four high-elevation seedlots:

Group number[1]	*Number of seedlots*	*Average total volume cu. ft./acre*	*North latitude*		
			Average	*Minimum*	*Maximum*
1	14	825	51°15′	46°38′	54°08′
2	16	791	51°38′	46°38′	54°08′
3	18	761	51°48′	46°38′	55°58′
4	17	753	51°49′	46°38′	55°58′
5	11	687	53°07′	49°20′	57°03′
6	3	458	57°14′	56°40′	58°00′
7	5	408	57°55′	56°40′	60°03′
8	7	319	59°14′	56°40′	61°44′

[1]Group No. 1 includes the 14 seedlots in the topmost bracket in table 5, group No. 2 the next lower bracket, and so on.

The above summary indicates the negative correlation between north latitude and total volume production. The average latitude for highest average volume production (753-825 cubic feet per acre) is between 51° and 52°; the minimum-maximum range is from 46° 38′ to 55° 58′. The data indicate that for *maximum assurance* of a minimum volume of approximately 750 cubic feet per acre at 18 years the parent provenance should not be above 52° north latitude and not higher than 500 meters in elevation. For a minimum volume of approximately 650 cubic feet per acre at 18 years the latitude of the parent provenance may be extended to 55° north latitude (fig. 9).

Since significant grouping of the seedlot means is not possible, it has been deemed advisable, for practical purposes, to rank the seedlots arbitrarily into five classes representing 20 percent of the range in estimated volume per acre (216 cubic feet to 973 cubic feet). These five arbitrary groupings have been numbered rank 1 (representing the top 20 percent in volume per acre) to rank 5 (representing the lowest 20 percent) in table 6. The data in this table will be discussed in the following section.

Volume Per Acre By Trunk Classes

The living trees in each provenance have been grouped into three trunk classes based on the following criteria:

Trunk class I.—Straight, single-stem trees without any recognizable crook, sweep, lean, or forks.

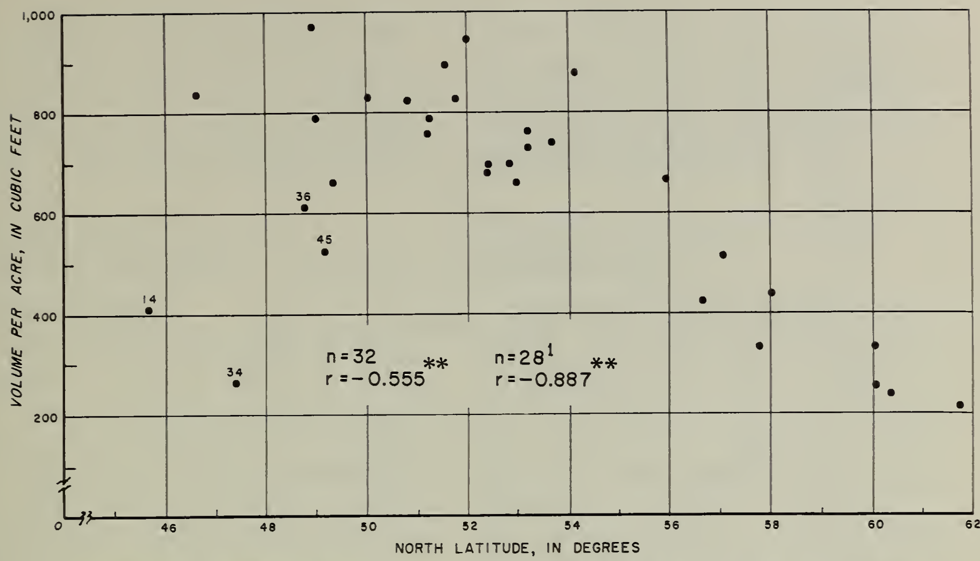

Figure 9.—Relationship between volume of all trees at 18 years and provenance latitude.
[1]The four provenances (14, 34, 36, 45) from parent stands above 500 meters elevation are excluded. **Correlation coefficient at the 1-percent level of significance with 30 d.f. = 0.449; with 26 d.f. = 0.478.

Trunk class II.—Trees without trunk crook, sweep, or lean producing an offset of 2 inches or more in the perpendicular axis of the stem, and without forks. Class II differs from class I in that it includes trees with offsets of less than 2 inches and trees with or without basal crook or sweep below a 2-foot stump height. In this classification it is assumed that crook, sweep, or lean resulting in less than 2 inches offset at 18 years will be outgrown in the mature trees at 60 to 80 years. Trees with basal crook or sweep of 2 inches or more are included in this class because this defect can be eliminated without serious loss of volume by cutting 2-foot high stumps. Actually there were relatively few trees in Class II with basal crook or sweep.

Trunk class III.—All trees not included in class I and II. These are trees with 2 inches or more trunk offset due to crook, sweep, or lean, and/or forks.

It might be expected that the location of seedlots B and H.B. as border row-plots in all replicates might influence their stem form. Although these progenies were somewhat more heavily branched, there was no indication of any appreciable effect on stem crook, lean, or sweep at 18 years.

The average volumes per acre, for each of the three trunk classes, arranged in descending order and ranked as for total volume, are listed in table 6. Selection of provenances for a variety of use objectives may be made from this table. For example, if the management objective is maximum production of cellulose, without regard for timber form, the provenances ranked 1 and the upper half of those ranked 2 under total volume should be preferred. If the objective

Table 6.—Volume per acre and rank at 18 years, by total volume and trunk classes

Total volume			Trunk class III			Trunk class II			Trunk class I		
Seedlot*	Volume	Rank**	Seedlot*	Volume	Rank**	Seedlot*	Volume	Rank**	Seedlot*	Volume	Rank**
	Cu.ft.			Cu.ft.			Cu.ft.			Cu.ft.	
35	973	1	35	885	1	38	224	1	37	167	1
H.B.	947		H.B.	804		55	212		32	134	
33	892		246	769		(36)	208		11	128	2
246	885		24	733		22	207		(45)	126	
53	874		232	727		40	200		33	124	
25	839		33	714	2	53	193		39	124	
20	825		20	668		B	182	2	30	105	
24	823		25	654		32	168		(34)	101	
41	820	2	53	628		54	160		41	99	3
44	791		19	627		(14)	156		44	95	
232	790		23	592		243	154		29	94	
55	786		41	573		41	148		38	94	
37	760		54	569		9	145	3	(36)	79	
54	759		44	562		44	134		25	76	
B	757		B	559	3	20	124		22	67	
22	740		55	534		H.B.	123		48	60	4
38	722		37	531		21	112		3	59	
19	696		39	522		25	109	4	53	53	
40	692		21	494		49	109		21	52	
39	687		40	471		(45)	100		49	50	
32	671		22	466		29	94		(14)	49	
23	664	3	38	404		246	89		55	40	
21	658		32	369	4	35	88		243	40	
(36)	611		(36)	324		(34)	83		20	33	
(45)	524		11	316		24	82		54	30	5
11	510	4	(45)	298		48	81		246	27	
243	439		9	258		23	66	5	9	22	
9	425		243	245		11	66		40	21	
(14)	411		(14)	206	5	37	60		H.B.	20	
29	336	5	49	172		19	55		232	16	
49	331		29	148		33	54		B	16	
(34)	260		3	116		232	47		19	14	
30	250		30	110		3	41		24	8	
48	239		48	98		39	41		23	6	
3	216		(34)	76		30	35		35	0	

*Numbers in parentheses are the high-altitude seedlots.

**Rank 1 includes the top 20 percent; rank 5 includes the lowest 20 percent.

is cellulose and quality timber requiring straight trunks, the provenances ranked 1 and 2 in class I or class II could be used in mixture with those in the upper ratings in class III.

Relationship between Volume Per Acre and Latitude

Two analyses were made to determine the correlation between volume per acre and latitude of the parent stand. One included the 32 seedlots for which data on latitude were available; the other, to determine the effect of elevation, included only 28 seedlots (omitting the four seedlots, 14, 34, 36, and 45 from parent stands over 500 meters in elevation). The negative correlations, calculated in both ways, were highly significant for total volume and for trunk class III but were not significant for classes I and II. The data for volume of all trees are plotted by volume over latitude in fig. 9.

For total volume and for class III the percent of the variation accounted for by the correlations based on 32 seedlots is 31 percent and 27 percent respectively; excluding the four low-latitude, high-elevation seedlots, the variation accounted for is much higher —79 percent in both cases. These correlations strengthen the conclusion that for maximum assurance of highest volume production under environments similar to those of the plantation site, it is advisable to obtain seed from latitudes south of 52° and elevations below 500 meters.

The lack of significant correlations between volume per acre and latitude for trunk classes I and II is due to the fact that although the number of trees in these trunk classes is generally higher in the more northerly seed sources, the growth rate of these provenances is relatively slow. The volumes in these classes do not indicate the correlation that is apparent on the basis of number of trees.

Number of Trees Per Acre and Latitude

The relationship of number of trees per acre and latitude for trunk classes I and II is shown in figures 10 and 11. For trunk class I the correlation based on 32 seedlots was significant at the 5-percent level; excluding the four high-elevation seedlots, the correlation was significant at the 1-percent level. For trunk class II the correlation was not significant on the basis of all 32 seedlots but was highly significant without the four high-elevation seedlots. The variation accounted for by the correlations based on 28 seedlots (omitting the four seedlots from elevations above 500 meters) is 51 percent for trunk class I and 25 percent for trunk class II.

The provenances have been ranked in five 20-percent categories on the basis of number of trees per acre in classes I and II (table 7) to guide the forest manager who may wish to base his provenance selection on a minimum number of class I or II crop trees at 18 years. As an example, the provenances ranked 1, 2, and 3 in class I may be expected to provide a minimum of 100 straight crop trees per acre at 18 years; if the management plan requires an expected minimum of 150 trees per acre, the provenances in rank 1 and 2 should be considered. Where trunk class II will satisfy the management objective, the provenances may be selected from ranks 1 and 2 for 150 crop trees per acre, or from ranks 1, 2, and 3 for 100 crop trees per acre.

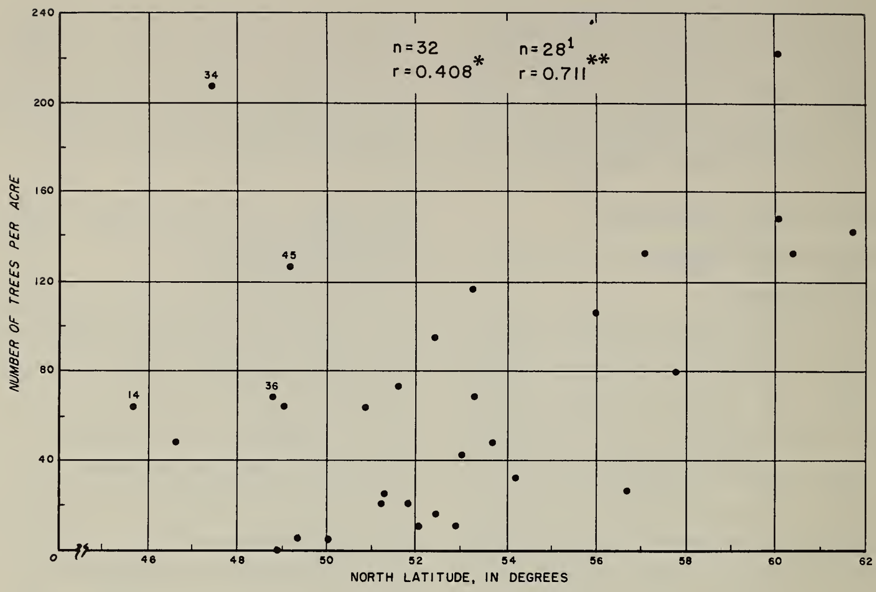

Figure 10.—Relationship between number of trees in trunk class I at 18 years and provenance latitude.

[1]The four provenances (14, 34, 36, 45) from parent stands above 500 meters elevation are excluded. *Correlation coefficient at the 5-percent level of significance with 30 d.f. = 0.349; **at the 1-percent level of significance with 26 d.f. = 0.478.

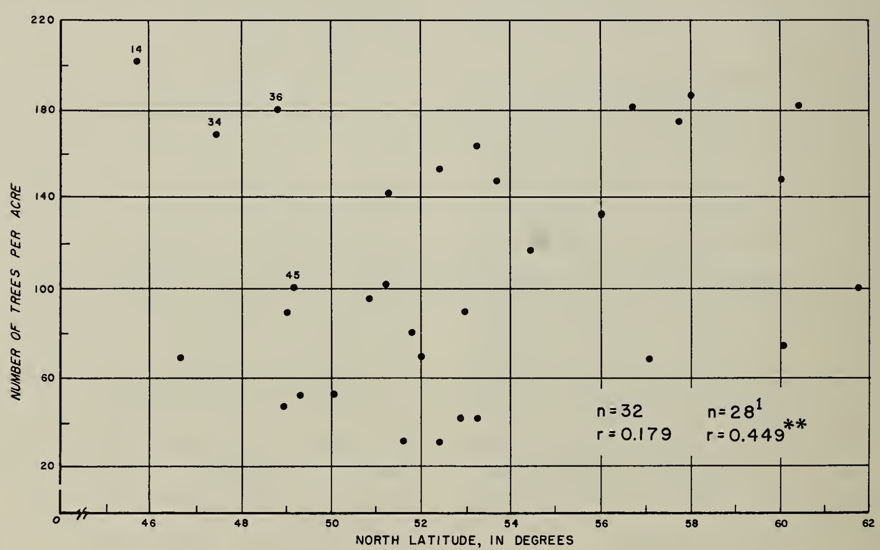

Figure 11.—Relationship between number of trees in trunk class II at 18 years and provenance latitude.

[1]The four provenances (14, 34, 36, 45) from parent stands above 500 meters elevation are excluded. **Correlation coefficient at the 1-percent level of significance with 26 d.f. = 0.478; at the 5-percent level of significance with 30 d.f. = 0.349.

Obviously volume production should also be considered in the selection of provenances. Seedlot 48 produced 133 class I trees per acre (table 7) with a volume of only 60 cubic feet per acre (table 6); the 133 class I trees in seedlot 11 produced 128 cubic feet; and seedlot 37, with 117 class I trees, produced 167 cubic feet per acre in 18 years.

Table 7.—Trees per acre and rank at 18 years

Trunk Class II

Seedlot number*	Trees per acre	Rank**
(14)	202	1
243	186	
48	181	
(36)	181	
9	181	
49	175	
(34)	170	
38	165	2
40	154	
29	149	
22	149	
55	143	
32	133	3
B	127	
53	117	
54	112	
(45)	101	
3	101	
41	96	4
44	90	
21	90	
20	80	
30	74	
H.B.	69	
11	69	
25	69	
246	53	5
23	53	
24	53	
35	48	
37	42	
19	42	
33	32	
232	32	
39	32	

Trunk Class I

Seedlot number*	Trees per acre	Rank**
30	223	1
(34)	207	
29	149	2
3	143	
48	133	3
11	133	
(45)	127	
37	117	
32	106	
39	96	
49	80	4
33	74	
38	69	
(36)	69	
44	64	
41	64	
(14)	64	
25	48	
243	48	
22	48	
21	42	5
53	32	
55	27	
9	27	
54	21	
20	21	
40	16	
246	16	
H.B.	11	
232	11	
B	11	
19	11	
24	5	
23	5	
35	0	

*Numbers in parentheses are the high-elevation seedlots.

**Rank 1 includes the top 20 percent; rank 5 includes the lowest 20 percent.

Summary and Recommendations

This is a report on the practical aspects of an 18-year-old provenance test involving 43 seedlots of Scotch pine in plantations located in Herkimer County, New York, at 43° 18′ north latitude and 75° 07′ west longitude. The seed was sown on two different sites in the New York State Forest Nursery at Saratoga in the spring of 1938. Thirty-five of the seedlots were outplanted as 2-0 stock in 1940 and 8 slow-growing seedlots from north Scandinavia (between 62° 22′ and 69° 06′ north latitude) were outplanted as 2-2 stock in 1942.

Fall needle color, important for Christmas tree production, was evaluated in the nursery at the end of the first and second growing seasons. The results confirm numerous reports that green winter foliage color is characteristic of Scotch pine of southern origins. If seedling ratings are accepted as indicative of needle color in 6- to 10-year-old trees, 12 of these provenances from latitudes between 46° and 53° would be satisfactory for use in this region.

Correlations between first- and second-year height in the nursery and 18-year height in the plantation were significant at the 5- and 1-percent levels. Under the conditions of this experiment, however, selection on the basis of provenances in the top 20 percent in average first- and second-year height on each of the two nursery sites would have included only 5.6 to 16.7 percent of the seedlots that were in the top 20 percent for height growth at 18 years. Selection based on first-year average height on both nursery sites would have included only 6.7 percent, on second-year average height only 40 percent of the top 20 percent at 18 years.

For practical purposes the provenances have been evaluated on the estimated 18-year total volume per acre, and on the volume per acre and number of trees per acre in three trunk classes that the authors believe represent a fair estimate of the probable quality of the mature timber.

The average latitude for seedlots with the highest average total volume at 18 years (753 to 825 cubic feet per acre) was between 51° and 52° north latitude, with a range of 46° 38′ to 55° 58′.

The differences between seedlots in total estimated volume per acre were highly significant but the means, compared by the studentized range method, fall into 8 widely overlapping groups. Since this overlap, indicating continuous variation, makes it impossible to segregate the provenances into distinct geographic groups, the provenances have been rated in five arbitrary categories representing 20 percent of the total variation in volume per acre of all trees (total volume) and in volume and number of trees per acre by trunk classes.

The results of this evaluation warrant the following recommendations:

- The provenances from northern Scandinavia (62°22′ to 69°06′ north latitude) are so slow-growing that they cannot be recommended for timber or Christmas tree production in this test region.
- For environments reasonably similar to the Saratoga, N. Y., area, Scotch pine from origins south of 53° north latitude and elevations

below 500 meters should be selected for maximum assurance of fall needle color acceptable for Christmas trees.

- For environments reasonably similar to the described plantation site, the provenance of the parent Scotch pine stands should be south of 52° north latitude and below 500 meters (1,640 feet) in elevation for maximum assurance of a minimum volume of 750 cubic feet per acre at 18 years. For a minimum of 650 cubic feet per acre the latitude of the parent provenance may be extended to approximately 55° north latitude. The ratings of the provenances in this experiment on the basis of 18-year volume and number of trees per acre by trunk classes are recommended for the selection of Scotch pine seed sources for particular production objectives.

- With limited nursery replication, selection of Scotch pine progenies in the top 20 percent in first- and second-year height growth in the nursery should not be assumed to include the majority of progenies that will be in the top 20 percent at 18 years.

- Seedling needle length in Scotch pine can be a useful criterion in juvenile selection for potential volume growth.

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